Comparing Outcomes between Arthroscopic-Assisted Reduction and Fluoroscopic Reduction in AO Type C Distal Radius Fracture Treatment

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Abstract

Background Distal radius fracture is one of the most common injuries. Poor functional result with restricted wrist motion can be developed when there is intra-articular fibrous tissue development arising from articular step-off and gapping.

Objectives The aim of this study is to compare the functional and radiological outcome between arthroscopic-assisted reduction and fluoroscopic reduction in treating unstable intra-articular distal radius fracture.

Methods We retrospectively analyzed 12 patients with intraarticular AO type C distal radius fracture treated with arthroscopic-assisted fracture reduction and internal fixation and compared them with another group of 12 patients in which fracture reduction is assessed by fluoroscopy alone (15 males and 9 females, mean age 57.3, range 27–73). The two cohorts were analyzed for differences in radiological parameters including articular stepping and gapping, palmar tilt, radial inclination, ulnar variance as well as functional outcome in range of motion, grip strength, modified mayo wrist score, and Quick Disabilities of the Arm, Shoulder, and Hand (DASH) score at an average of 12.5 months (range 5–26) after surgery.

Results Arthroscopic-assisted fracture reduction group has statistically better restoration of articular stepping and gapping, volar tilt and ulnar variance. Range of motion, grip strength, modified mayo wrist score and Quick DASH score also had statistically significant improvement in arthroscopic group.

Conclusion Our study showed arthroscopic-assisted technique can precisely restore radiological parameters in highly comminuted distal radius fracture with good functional outcome. Also, associated intra-articular soft tissue injury can be detected and treated simultaneously.

Level of Evidence This is a level III, retrospective cohort study.

Keywords
- distal radius fracture
- wrist arthroscopy
- arthroscopic assisted reduction
- concomitant injuries

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Distal radius fracture is one of the most common injuries and accounts for 15% of all fractures.[1] Treatment methods can vary from cast immobilization to open reduction and internal fixation depending on the fracture fragment alignment, radial height, anatomical reduction of the articular surface, intra-articular soft tissue injuries, and patient's functional demands. Articular step-off more than 2 mm and articular gapping lead to poor functional results and radiocarpal arthritis in 7 years follow-up has been mentioned.[2,3] The underlying reason that lead to poor functional outcome has been explored by Gabl et al, who performed wrist arthroscopy in 20 patients at the time of implant removal. The arthroscopic findings showed there is fibrous tissue development extended from previous intra-articular gap to the surrounding structures and this leads to restricted wrist motion.[4]

Therefore, restoration of articular anatomy to prevent later restrictive fibrous tissue formation has become the main goal in intra-articular distal radius fracture treatment. Fluoroscopy is the conventional method to assess the articular congruity during the operation. But at some occasions, it underestimates the quality of residual articular step and gap deformity. Under better magnification and lighting, articular surface can be better visualized with the use of arthroscope which can be helpful in reduction of displaced articular fragment.[5]

So, we are trying to assess whether additional arthroscopic-assisted fracture reduction technique can improve the distal radius articular congruity and radiological parameters that lead to better restoration of wrist function. The aim of the study is to compare the functional and radiological outcome between arthroscopic-assisted fracture reduction and fluoroscopic fracture reduction in treating highly unstable intra-articular AO type C distal radius fracture.

Patients and Methods

The research project had been approved and registered under Joint CUHK-NTEC Clinical Research Ethics Committee (reference number: CREC 2020.182) and strict confidentiality guidelines were followed.

All patients 18 years of age or older with unilateral AO type C unstable distal radius fracture sustained between April 2016 and March 2018 were recruited for study inclusion. Dorsal or volar angulation more than 20 degrees, dorsal cortical comminution, intra-articular radiocarpal joint fracture with articular step or gap more than 2 mm and radial shortening for more than 10 mm were the indications for proceeding to open reduction and internal fixation.[6–8] Patients who suffered from open fracture, multiple limb injuries, and pathological fractures, unable to attend post-operative physiotherapy, and follow-up period less than 3 months were excluded from the study.

Demographic data of patients including age, gender, fracture type, and hand dominance were collected through the electronic clinical management system.

Surgical Techniques

All surgeries were performed by specialist level surgeons and the procedure was performed under general anesthesia. Patient was lying supine and the operated arm was placed over the radiolucent arm board with tourniquet applied over the upper arm. Volar Henry approach to distal radius was used for exploration of distal radius fracture. Once fracture reduction was deemed satisfactory, distal radius volar locking plate was applied for all cases. Additional dorsal distal radius plating was utilized according to fracture configuration as shown in preoperative X-ray and computed tomography (CT) scan.

Fluoroscopic-Assisted Reduction and Internal Fixation (Fluoroscopic Group)

For fluoroscopic group, fluoroscopy was only used for assessing fracture reduction. Fracture was approached as mentioned above. Once the fracture reduction was reduced, 1.6-mm K-wires were inserted to stabilize the fracture. Fluoroscopic images were obtained to evaluate the articular reduction, including standard posteroanterior (PA) view, lateral view, anatomical PA (11 degrees tilt), and lateral 23 degrees tilt views.[9] The volar locking plate was applied once the fracture reduction is considered satisfactory.

Plate system used was based on surgeon preference and was either Synthes 2.4-mm Variable Angle Locking Compression Plate Distal Radius System (DePuy-Synthes, West Chester, PA) or Aptus Wrist Distal Radius System 2.5 mm (Medartis, Kennett square, PA).

Arthroscopic-Assisted Reduction and Internal Fixation (Arthroscopic Group)

In arthroscopic group, fracture reduction sequence started from the volar part of intermediate column, where the cortex was thickest and easier to reduce, followed by volar part of radial column (►**Fig. 1**). Then volar distal radius locking plate was temporarily fixed onto the radius by inserting a single cortical screw into the elliptical hole over the plate. Once the plate position including its relationship with distal radius watershed line and adequate plate coverage for radial and intermediate column achieved by the plate was achieved, additional locking screw over the proximal hole could be inserted to prevent later plate displacement. The volar distal radius plate now served as the buttress for the volar fragments, which can temporarily anchor the reduced fragments onto the plate with K-wires and it is ready for wrist arthroscopy assessment (►**Fig. 2**).

The operated arm of the patient was placed on the metal base plate of the sterilizable wrist traction Tower (ConMed Linvatec Corp., Goleta, CA), with shoulder abducted at 90 degrees, elbow flexed at 90 degrees, and forearm in neutral rotation. Ten to 12 pounds of traction force was sufficient for wrist joint distraction (►**Fig. 3**). A three-fourths and 6R portals were used for radiocarpal joint assessment while midcarpal joint surveillance was performed by MCU and MCRQ1 portals. Transverse superficial skin incision in line with the skin crease was created over the portal site to have better scar healing, using the tip of curved mosquito hemostat to gently dilate the portal site until the joint capsule was perforated. An arthroscopic cannula with blunt ended trocar was gently placed though the portal. After

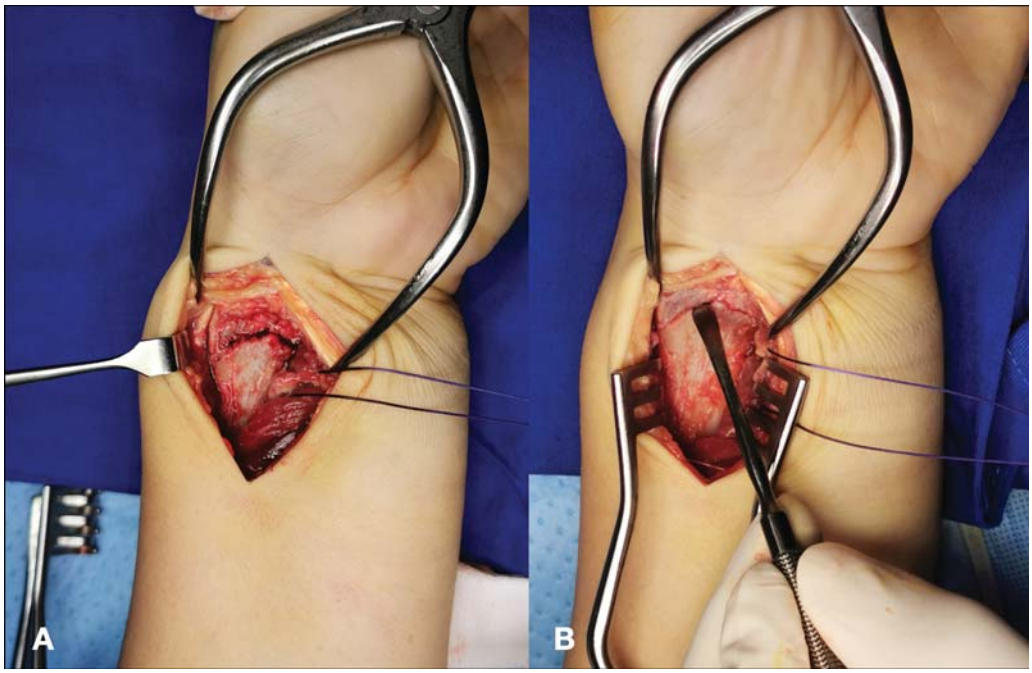

Fig. 1 (**A**) Intraoperative photo showing the distal radius fracture was explored through volar Henry approach and brachioradialis was released from distal fragment for easier reduction. (**B**) The distal radius volar fragment was temporarily reduced.

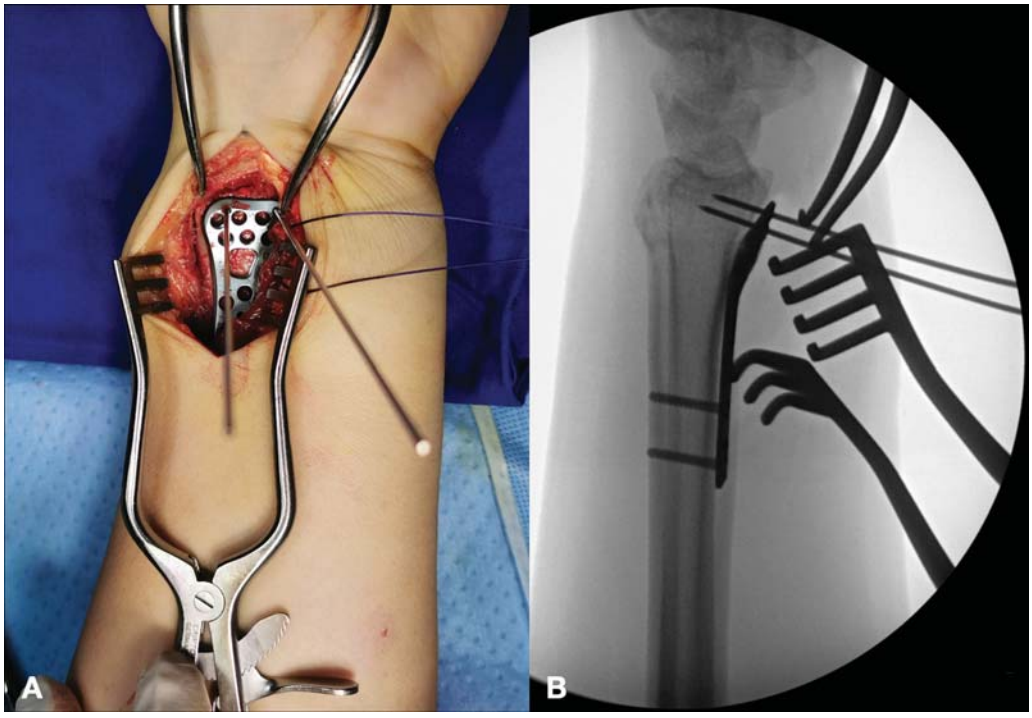

Fig. 2 (**A**) Intraoperative photo showing the volar distal radius locking plate was applied onto the radius. (**B**) The distal radius volar fragment was temporarily fixed onto the distal radius volar locking plate with two 1.2-mm K-wire through the hole on the plate as shown in intraoperative fluoroscopic film.

removing the trocar, the cannula was then connected by long tubing to a 3-L saline bag hanged at 1.5 m above to provide gravity driven inflow to the joint.

A 1.9-mm 30 degrees arthroscope was used. Initially three-fourths portal was established to aid in creating 6R portal which was subsequently used as main viewing portal. The advantage of using 6R portal as viewing portal was to prevent dorsal rim fragment depression accidentally when the arthroscope was placed over fourth-fifths portal. The ulnar head underneath the 6R portal could act as a stable platform for the arthroscope to work with. The visual field inside the wrist joint was usually obscured by intra-articular blood-stained joint fluid and hematoma. The visibility can be improved by using 10-mL syringe filled up with saline to

Fig. 3 Photo showing the usual setup for arthroscopic-assisted reduction for distal radius fracture. The operated arm was put onto the wrist traction tower with shoulder abducted to 90 degrees and elbow flexed in 90 degrees. Monitors for fluoroscopy and arthroscope were placed on the contralateral side of operation table. Three liters of normal saline was hanged at 1.5 m above to provide gravity driven inflow to the joint through the cannula.

irrigate the wrist joint. Afterward, hematoma and loose bodies that got stuck within the articular gap were removed with arthroscopic probe and shaver to facilitate articular fragment reduction (►**Fig. 4**). The volar K-wire that helped to temporarily stabilize the dorsal articular fragment was withdrawn backward a little bit to free the dorsal articular fragment for fine adjustment of fracture reduction. Articular fragment could be reduced either by joystick, or compression maneuver according to the articular fragment positioning and configuration[10] (►**Fig. 5**). Depressed free osteochondral fragment can be reduced by the pushed-up technique with the bended 2.0-mm K-wire through the window on the volar distal radius locking plate (►**Fig. 6**). The fracture gap between volar and dorsal articular fragment was reduced with the soft tissue bone reduction clamp (Synthes GmbH, Oberdorf, Switzerland) by pushing dorsal fragment onto the reduced volar fragment (►**Fig. 7**). Then the reduced fragment was temporarily held in position with K-wires either from dorsal or volar direction. Final fracture fixation was completed by inserting the locking screws adjacent to subchondral bone through the locking screw hole of volar distal radius plate.

After the distal radius fracture had been fixed, arthroscopic surveillance of radiocarpal and midcarpal joint looking out for any intra-articular soft tissue injuries was performed. Any scapholunate interosseous ligament (SLIL), lunotriquetral interosseous ligament (LTIL), and triangular fibrocartilage complex (TFCC) tear were identified and surgical repair was performed on cases with SLIL and LTIL Geissler III and IV as well as TFCC tear with unstable DRUJ where peripheral or fovea TFCC tear was suspected.

All patients, except those had repair of intra-articular soft tissue injury, received the same postoperative rehabilitation program. Active finger, wrist, and forearm rotational exercises were started right after the operation. Passive range of motion exercise and strengthening exercise was started at 6th and 8th weeks, respectively. Load-bearing exercise is not recommended before the 12th week.

Articular stepping and gapping after operative fixation as well as radiological assessment in radial inclination, radial height, ulnar variance was assessed by postoperative X-ray and CT scan using the longitudinal axis method mentioned by Catalano et al.[11]

Active range of motion in wrist flexion and extension, forearm pronation, and supination were measured with goniometer. Grip strength was measured by JAMAR hand dynamometer (Preston, Cambridge, MA) and compared with contralateral side. Together with Modified Mayo Wrist score and Quick Disabilities of the Arm, Shoulder, and Hand (DASH), patient was being assessed at 6, 12, 26, and 52 weeks postoperatively by an independent examiner who is unaware of the group assignments.

Statistical Analysis

The result of functional and radiological outcomes was analyzed with IBM SPSS 26.0 (Armonk, New York, NY). Continuous and categorical variables were compared using the Student's *t*-test and Chi-square test, respectively. $p \leq 0.05$ was considered to be statistically significant.

Results

Fifteen males and nine females were recruited into the study. The mean age was 57.3 (range 27–73). The AO fracture subtype was C-1 in six patients, C-2 in seven, and C-3 in 11. The dominant hand was affected in nine patients (36%). The average follow-up time was 12.5 months (range 5–26). Both arthroscopic group and fluoroscopic group had 12 patients. There were no statistically significant differences between the two groups with respect to age, gender, AO fracture type, and injury to the dominant side.

Concomitant intra-articular soft tissue injuries were detected in the arthroscopic group (five TFCC tear, three SLIL tear, and one LTIL tear) and were treated according to the indications mentioned above.

For the radiological evaluation, arthroscopic group has statistically significantly less articular stepping ($p = 0.02$) and gapping ($p < 0.01$) as well as better restoration in volar tilt ($p = 0.05$) and ulnar variance ($p = 0.02$). Also, the accuracy in restoring the four radiological measurements is much better in arthroscopic group as the standard deviation range is smaller in arthroscopic group.

Fig. 4 Radiocarpal joint was assessed from 6R portal showing that the hematoma interposed between the fracture fragment was removed by 2.0-mm arthroscopic shaver.

At final follow-up, range of motion improvement had been shown to be better in arthroscopic group. Wrist extension ($p < 0.01$) and flexion ($p = 0.04$), forearm pronation ($p = 0.03$) and supination ($p = 0.05$) as well as the percentage of grip strength restored ($p = 0.02$) showed statistically significant improvement when compared with fluoroscopic group.

When using Modified Mayo Wrist score for patient functional assessment, arthroscopic group had two excellent, two good, and eight satisfactory results, whereas fluoroscopic group had one good, eight satisfactory, and three poor results. The mean Modified Mayo Wrist score had statistically significant difference between the two groups ($p = 0.02$). However, the Quick DASH score failed to show any difference between the two groups ($p = 0.88$).

In our series, we did not have any acute compartment syndrome developed after the operation. There is no loss of fracture reduction as shown in subsequent X-ray and CT scan. No complex regional pain syndrome, extensor, or flexor tendon rupture was noted in our series. However, among the fluoroscopic group, there was progressive widening of scapholunate interval and DRUJ space with corresponding pain detected in three patients and one patient, respectively that requires further investigation and treatment in later stage. Upon assessment of possible intra-articular soft tissue injury using the wrist arthroscopy in these four patients, we could notice arthrofibrosis development from the fracture gap to the surrounding structures that require removal with arthroscopic shaver (►**Video 1**).

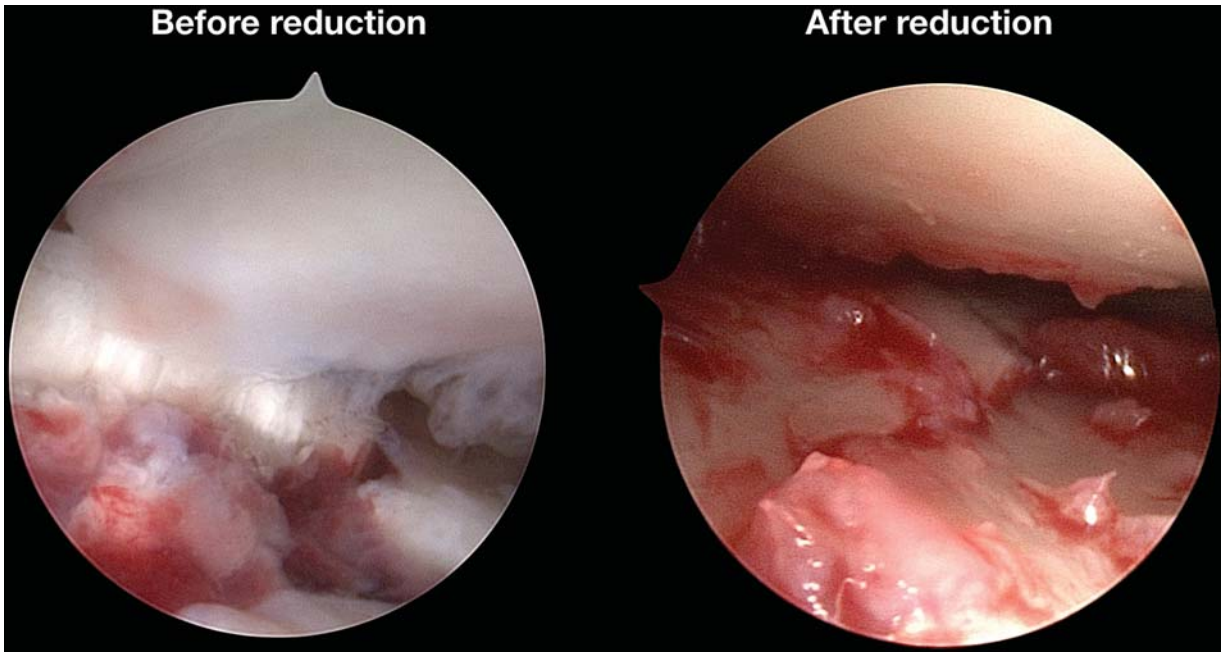

Fig. 5 Arthroscopic view as seen from 6R portal showing the difference in joint congruity before and after reduction of displaced articular fragment.

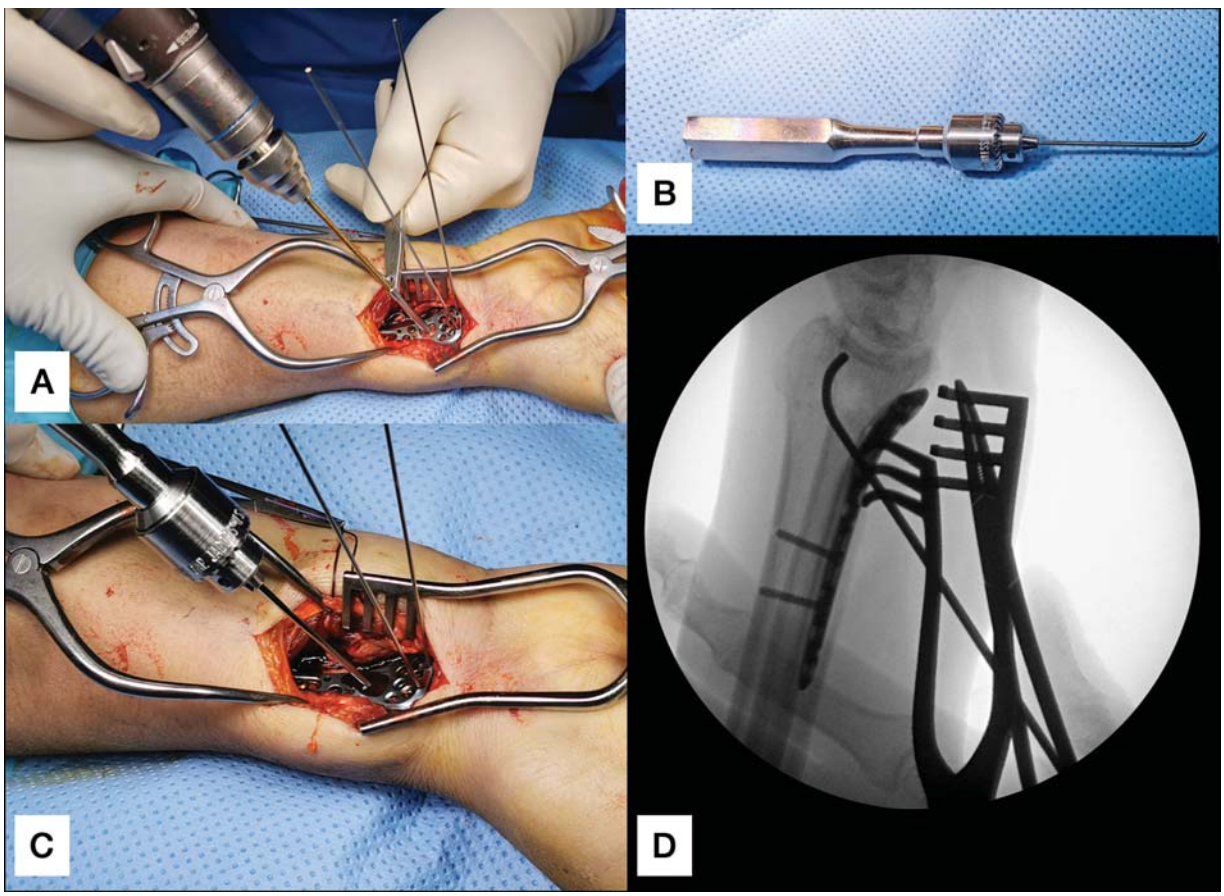

Fig. 6 Intraoperative photo showing the steps to reduce the depressed osteochondral fragment. (**A**) Cortical bone window is created over the window on the distal radius volar locking plate by 2.5-mm drill. (**B**) Blunt end of 2.0-mm K-wire is bended and put into pin introducer as a tool to reduce the articular fragment. (**C**) The bended K-wire was passed through the cortical bone window and (**D**) the depressed articular fragment is pushed back to original position as shown in fluoroscopic scan.

Fig. 7 The fracture gap between volar and dorsal articular fragment can be reduced with the soft tissue bone reduction clamp (Synthes GmbH, Oberdorf, Switzerland) by pushing dorsal fragment onto the reduced volar fragment.

Video 1

Wrist arthroscopic video clip, showing intra-articular findings from a patient, belongs to fluoroscopic group that requires further treatment due to painful progressive scapholunate interval widening. As viewed into radiocarpal joint through three-fourths portal, there are arthrofibrosis development from previous fracture gap and extended to surrounding structures. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0040-1719039.

Discussion

Articular stepping and gapping are the important factors that can affect the functional outcome in distal radius fracture.[2,3] Wrist arthroscopy is useful as an adjunct in restoring articular surface congruity because it provides excellent visualization of articular surface that cannot be provided by conventional fluoroscopy and therefore it has better ability to reduce articular stepping and gapping precisely. Second, the articular stepping and gapping are often underestimated when assessed under fluoroscopy.[5,12] Recent meta-analysis has looked into 28 papers related to the use of wrist arthroscopy in distal radius fracture which support the findings of better quality in intra-articular reduction with wrist arthroscopy and better prognosis when compared with fluoroscopy.[13]

But performing wrist arthroscopy in acute distal radius fracture is technically demanding and requires expertise in wrist arthroscopy. Yamazaki et al conclude that arthroscopic-assisted reduction does not improve radiological and functional outcomes in unstable intra-articular distal radius fractures.[14] The difficulty arises from the problem to establish good visual field inside the wrist joint when using arthroscope, lack of reference point to restore the articular surface, radial height and inclination and fear of extravasation causing acute compartment syndrome.

We connect the 10-mL syringe filled with saline to inflow portal of cannula, with suction provided from shaver creating a strong flow of saline irrigation helping to improve the visibility. Abe et al developed plate presetting arthroscopic reduction technique has simplified the distal radius fracture treatment by fixing the distal radius volar locking plate before introducing wrist arthroscopy and gained good clinical results.[15] Our technique aims to further simplify the reduction process and is different from his technique. Before temporarily fixing the volar locking plate to distal radius, we have purposely reduced the volar fragment of both radial and

intermediate column to restore the normal radial height and volar tilt angle of volar fragments first. Then, the distal radius locking plate is used as a buttress to hold the reduced volar fragments. This step helps us to have better estimation and restoration of radial height and volar tilt that are often lost in comminuted fracture. Using the reduced volar fragment as a reference point, reduction of the displaced dorsal fragments back onto the already reduced volar fragment makes the judgement on the adequacy about volar tilt and radial inclination restoration easier under arthroscopic viewing. We have refined this technique to make it easier to follow and particularly useful in extensively comminuted fracture such as intra-articular AO classification type C distal radius fracture. In our series, we do not have any acute compartment syndrome developed after the operation even if we use wet arthroscopy. Our operations are usually performed around 1 week after injury. Soft tissue swelling resolution and hematoma development probably decrease the extent of excessive compartmental pressure development and fluid extravasation. Also, we do not use power-driven fluid inflow system for wrist arthroscopy which can avoid fluid extravasation. Furthermore, introduction of 16-gauge hypodermic needle over 6U portal allows adequate fluid outflow from wrist joint. This can prevent excessive pressure development inside the joint that forces the fluid leaking out and causing iatrogenic compartment syndrome.

Ability to assess and treat concomitant intra-articular soft tissue injuries offers additional advantage in using wrist arthroscopy in distal radius fracture management. In study from Varitimidis et al, 15 out of 20 patients who had wrist arthroscopy performed were found to have intercarpal ligament and/or TFCC injuries.[16] In particular, SLIL and TFCC tears often accompany intra-articular distal radius fracture in 5 to 64% and 80%, respectively.[17–25] Treating high-grade SLIL injuries such as Geissler grade 3 and 4 with temporary scapholunate joint fixation is often recommended.[26] Ruch et al have demonstrated better outcome with TFCC repaired at the time of distal radius fracture treatment. Upon average follow-up time of 24 months (range 17–35 months), none of their 13 patients complain ulnar wrist pain. Gartland and Werley grading system was good to excellent in 12 patients and fair in one patient. Mean functional score of 13 and a mean athletic score of 12 were noted in DASH score.[27] Simultaneous repair of associated soft tissue lesions at the time of arthroscopic-assisted reduction of distal radius fracture was believed to lead to these improved outcomes.[16] Similar observations have been noticed in our study. But, to verify our findings, a prospective study with longer follow-up in the future is suggested as our study had several drawbacks including retrospective cohort study design with small sample size and short follow-up.

Our study showed wrist arthroscopy helps to improve the articular reduction by minimizing articular stepping and gapping resulting in statistically significant improvement of functional outcome. Also, using the technique that utilizes the distal radius volar locking plate as the buttress to reduce volar fragment and acts as starting point for fracture reduction and fixation, helps to restore all the distal radius radiological parameters. Moreover, intra-articular soft tissue injury can be detected and repaired accordingly with the use of wrist arthroscopy.

Ethical Approval

This research project is approved and registered under Joint CUHK-NTEC Clinical Research Ethics Committee, with the reference number of CREC 2020.182.

Authors' Contributions

The patients were recruited and treated in Alice Ho Miu Ling Nethersole Hospital. S.C.J.J.K. researched literature conceived the study, led to protocol development, gaining ethical approval, and manuscript writing. S.C.J.J.K. and K.Y.A.L. conducted patient assessment. W.W.C. performed data analysis. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Conflict of Interest

None declared.

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References

1 Ruch DS, Weiland AJ, Wolfe SW, Geissler WB, Cohen MS, Jupiter JB. Current concepts in the treatment of distal radial fractures. Instr Course Lect 2004;53:389–401
2 Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am 1986;68(05): 647–659
3 Trumble TE, Schmitt SR, Vedder NB. Factors affecting functional outcome of displaced intra-articular distal radius fractures. J Hand Surg Am 1994;19(02):325–340
4 Gabl M, Arora R, Klauser AS, Schmidle G. Characteristics of secondary arthrofibrosis after intra-articular distal radius fracture. Arch Orthop Trauma Surg 2016;136(08):1181–1188
5 Edwards CC II, Haraszti CJ, McGillivary GR, Gutow AP. Intra-articular distal radius fractures: arthroscopic assessment of radiographically assisted reduction. J Hand Surg Am 2001;26(06): 1036–1041
6 Cooney WP III, Linscheid RL, Dobyns JH. External pin fixation for unstable Colles' fractures. J Bone Joint Surg Am 1979;61(6A):840–845
7 Lafontaine M, Delince P, Hardy D, Simons M. Instability of fractures of the lower end of the radius: apropos of a series of 167 cases. Acta Orthop Belg 1989;55(02):203–216
8 Walenkamp MM, Vos LM, Strackee SD, Goslings JC, Schep NW. The unstable distal radius fracture-how do we define it? A systematic review. J Wrist Surg 2015;4(04):307–316
9 Boyer MI, Korcek KJ, Gelberman RH, Gilula LA, Ditsios K, Evanoff BA. Anatomic tilt x-rays of the distal radius: an ex vivo analysis of surgical fixation. J Hand Surg Am 2004;29(01):116–122
10 Del Piñal F. Technical tips for (dry) arthroscopic reduction and internal fixation of distal radius fractures. J Hand Surg Am 2011; 36(10):1694–1705
11 Catalano LW III, Barron OA, Glickel SZ. Assessment of articular displacement of distal radius fractures. Clin Orthop Relat Res 2004;(423):79–84
12 Lutsky K, Boyer MI, Steffen JA, Goldfarb CA. Arthroscopic assessment of intra-articular distal radius fractures after open

reduction and internal fixation from a volar approach. J Hand Surg Am 2008;33(04):476–484
13 Smeraglia F, Del Buono A, Maffulli N. Wrist arthroscopy in the management of articular distal radius fractures. Br Med Bull 2016;119(01):157–165
14 Yamazaki H, Uchiyama S, Komatsu M, et al. Arthroscopic assistance does not improve the functional or radiographic outcome of unstable intra-articular distal radial fractures treated with a volar locking plate: a randomised controlled trial. Bone Joint J 2015;97-B(07):957–962
15 Abe Y, Yoshida K, Tominaga Y. Less invasive surgery with wrist arthroscopy for distal radius fracture. J Orthop Sci 2013;18(03):398–404
16 Varitimidis SE, Basdekis GK, Dailiana ZH, Hantes ME, Bargiotas K, Malizos K. Treatment of intra-articular fractures of the distal radius: fluoroscopic or arthroscopic reduction? J Bone Joint Surg Br 2008;90(06):778–785
17 Forward DP, Lindau TR, Melsom DS. Intercarpal ligament injuries associated with fractures of the distal part of the radius. J Bone Joint Surg Am 2007;89(11):2334–2340
18 Geissler WB. Arthroscopically assisted reduction of intra-articular fractures of the distal radius. Hand Clin 1995;11(01):19–29
19 Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am 1996;78(03):357–365
20 Gunal I, Ozaksoy D, Altay T, Satoglu IS, Kazimoglu C, Sener M. Scapholunate dissociation associated with distal radius fractures. Eur J Orthop Surg Traumatol 2013;23(08):877–881
21 Lee JS, Galla A, Shaw RL, Harris JH. Signs of acute carpal instability associated with distal radial fracture. Emerg Radiol 1995;2(02):77–83
22 Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg [Br] 1997;22(05):638–643
23 Mrkonjic A, Lindau T, Geijer M, Tägil M. Arthroscopically diagnosed scapholunate ligament injuries associated with distal radial fractures: a 13- to 15-year follow-up. J Hand Surg Am 2015;40(06):1077–1082
24 Richards RS, Bennett JD, Roth JH, Milne K Jr. Arthroscopic diagnosis of intra-articular soft tissue injuries associated with distal radial fractures. J Hand Surg Am 1997;22(05):772–776
25 Rosenthal DI, Schwartz M, Phillips WC, Jupiter J. Fracture of the radius with instability of the wrist. AJR Am J Roentgenol 1983;141(01):113–116
26 Yoshida S, Yoshida K, Sakai K, Nakama K, Shiba N. Frequency of scapholunate ligament injuries associated with distal radius shearing fracture: correlation of fracture patterns and ligament tear. Hand Surg 2015;20(03):440–446
27 Ruch DS, Yang CC, Smith BP. Results of acute arthroscopically repaired triangular fibrocartilage complex injuries associated with intra-articular distal radius fractures. Arthroscopy 2003;19(05):511–516